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3D-Cinematic rendering for dental and maxillofacial imaging

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Abstract: OBJECTIVES Aim of this technical note is to show the applicability of cinematic rendering (CR) for a photorealistic 3-dimensional (3D) visualization of maxillofacial structures. The focus is on maxillofacial hard tissue pathologies. METHODS High density maxillofacial pathologies were selected in which CR is applicable. Data from both, computed tomography (CT) and cone beam computed tomography (CBCT) were postprocessed using a prototype CR software. RESULTS CR 3D postprocessing of CT and CBCT imaging data is applicable on high density structures and pathologies such as bones, teeth, and tissue calcifications. Image reconstruction allows for a detailed visualization of surface structures, their plasticity, and 3D configuration. CONCLUSIONS CR allows for the generation of photorealistic 3D reconstructions of high density structures and pathologies. Potential applications for maxillofacial bone and tooth imaging are given and examples for CT and CBCT images are displayed.

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TECHNICAL REPORT

3D-cinematic rendering for dental and maxillofacial imaging

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Objectives: Aim of this technical note is to show the applicability of cinematic rendering (CR) for a photorealistic 3-dimensional (3D) visualization of maxillofacial structures. The focus is on maxillofacial hard tissue pathologies.
Methods: High density maxillofacial pathologies were selected in which CR is applicable. Data from both, CT and cone beam CT (CBCT) were postprocessed using a prototype CR software.
Results: CR 3D postprocessing of CT and CBCT imaging data is applicable on high density structures and pathologies such as bones, teeth, and tissue calcifications. Image reconstruction allows for a detailed visualization of surface structures, their plasticity, and 3D configuration.
Conclusions: CR allows for the generation of photorealistic 3D reconstructions of high density structures and pathologies. Potential applications for maxillofacial bone and tooth imaging are given and examples for CT and CBCT images are displayed.
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Keywords: cone-beam CT; multidetector CT; maxillofacial abnormalities; imaging; three-dimensional

Introduction

Three-dimensional (3D) image reconstructions are established for an advanced image analysis and are known for their useful support to display and to assess anatomical and pathological structures in clinical routine. They enable and facilitate an overview and a better understanding of complex pathologies and allow for other applications such as for patient demonstrations and teaching purposes for medical students or residents. Currently, the conventional volume rendering technique (VRT) is the most common method used in imaging with well-known benefits for the detection, interpretation, diagnosis, and for treatment planning of dentomaxillofacial lesions.[1–3]

Cinematic rendering (CR) is a relative recently introduced postprocessing technique, which is based on an advanced 3D algorithm. It allows for a more photorealistic visualization of structures and lesions compared to standard VRT postprocessing. CR images appear highly realistic and recent studies have shown superiority regarding the depiction and understandability of image findings compared to VRT reconstructions.[4,5] Various publications used CT-based imaging data for CR illustrations such as in abdominal and cardiac imaging or in musculoskeletal trauma.[6–8] In a recent publication, Rowe et al. demonstrated potential applications of CR for structures and pathologies of the calvarium, the skull base, and maxillofacial structures. However, focus was not set on dental structures and they did not investigate into the use of data from cone beam CT (CBCT).[9] The latter imaging modality plays a major role in today's maxillofacial imaging, since CBCT provides detailed images of dental structures and bones, enables a fast and precise treatment planning, and requires substantial lower radiation dose compared to conventional multidetector CT.[10]

The present technical note uses CT and CBCT data for CR illustrations of maxillofacial anatomy and further special focus was given on pathologies, fractures, and tooth structures.

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Methods and materials

Representative examples of lesions of the maxillofacial region were identified in which an application of CR might be possible. Routine clinical data were acquired by either CT (case 1 and 3) or CBCT (case 2 and 4). All included patients or their guardians gave consent to the use of health-related data and their images. CT imaging was performed either on a Somatom definition AS plus CT scanner (case 1) or on a second-generation 128-slice dual-source Somatom definition flash CT scanner in single energy mode (case 3) (both Siemens Healthineers, Forchheim, Germany) applying the standard imaging parameters used at our institution for clinical imaging routine: Non-contrast CT of the head, slice thickness of 0.75 mm, tube voltage 120 kVp, and automated tube current modulation (CAREDose4D) with 372 mAs as dose reference.

Cone beam CT imaging was performed on a Morita Accuitomo Scanner (J. Morita, Accuitomo 170, Kyoto, Japan) with the following imaging parameters: Case 2: image acquisition voxel size $0.080 \times 0.080 \times 0.080\,mm^3$, reconstructed slice thickness 0.960 mm, slice interval 0.480. Case 4: image acquisition voxel size $0.250 \times 0.250 \times 0.250\,mm^3$, reconstructed slice thickness 1.0 mm, slice interval 0.5. CBCT images were visualized, using the OnDemand 3DApp Software (CyberMed, Seoul, Korea).

CR images were reconstructed using a prototype rendering software (Cinematic Rendering Version 1.5.3, syngo.via Frontier, Version VB30, Siemens Healthineers, Forchheim, Germany).

Image examples are given for common dentomaxillofacial lesions, by means of dysgnathia, tooth fracture, fracture of the mandible, and salivary stone disease (case 1-4).

Results

High density structures and pathologies can be displayed in CR reconstructed datasets. Image examples are given for common dentomaxillofacial lesions (case 1-4; Figures 1–4).

Image example 1

Facial skeleton: Dysganthia with a vertical open bite and occlusal contact of the molar teeth. The mandible shows pronounced vertical growth. (Figure 1a-f) CR imaging visualizes the occlusal contact of the last two molar teeth with non-occlusion starting from the first molar to the anterior teeth. In this example, CR can capture the three-dimensionality of the open bite in a photorealistic manner.

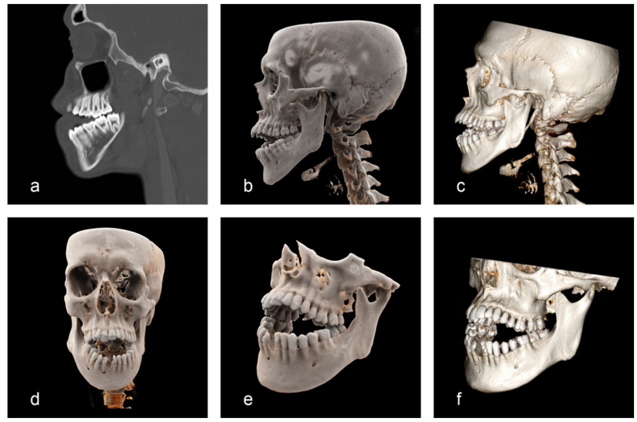

Figure 1 Dysganthia with a vertical open bite: a) sagittal CT plane; (b) sagittal CR view; (c) sagittal conventional VRT view; (d) frontal CR view; (e) oblique CR view; (f) oblique conventional VRT view.

Image example 2

Post traumatic root fracture of tooth 21. (Figure 2a-d) Figure 2a shows a classical sagittal CBCT view of the tooth within the alveolar process. The oblique view using CR (Figure 2d) visualizes the root surface and the vestibular fracture line. Figure 2b shows a sagittal view of the root fracture gap at the crestal bone level using CR. The root fracture shows a curved fracture line in the palatinal half of the root. The CR technique enables a clear three-dimensional understanding of the fracture line, also visualizing the pulp cavity.

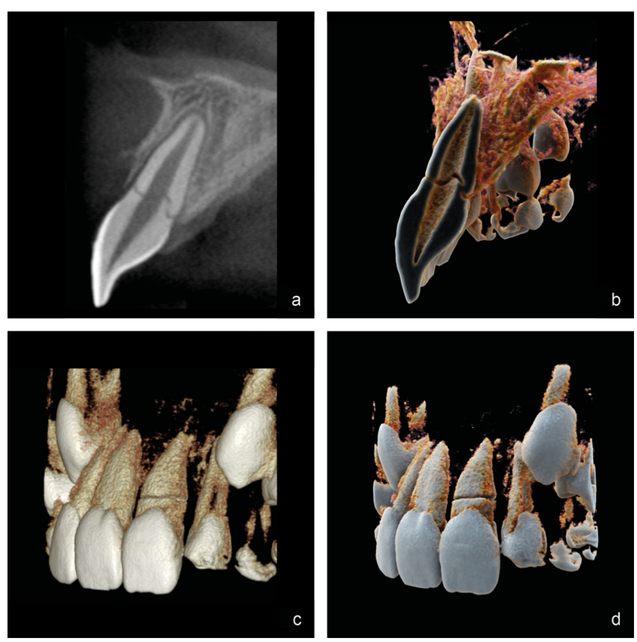

Figure 2 Root fracture of tooth 21: (a) sagittal CBCT plane; (b) sagittal CR plane; (c) oblique conventional VRT view; (d) oblique CR view.

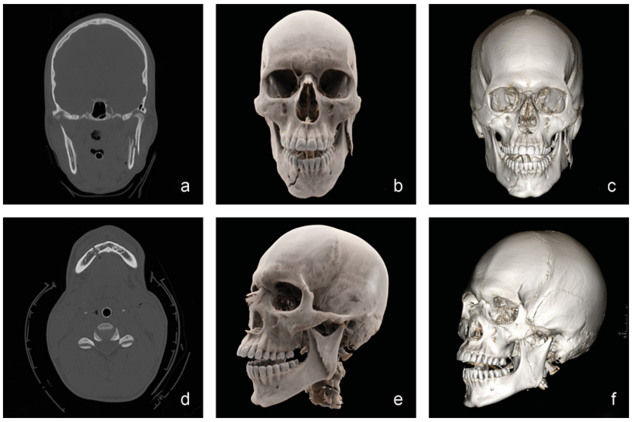

Figure 3 Paramedian (right) and ramus (left) fracture of the mandible: (a) frontal CT plane; (b) frontal CR view; (c) frontal conventional VRT view; (d) axial CT plane; (e) oblique CR view; (f) oblique conventional VRT view.

Image example 3

Mandibular fracture: traumatic fracture of the left mandibular ramus and a paramedian fracture of the right mandibular corpus. (Figure 3a–f) The ramus fracture was displaced to the lateral side, which can be easily perceived in the frontal CR view in Figure 3b. In contrast to the conventional volume rendering in Figure 3c, spatial depth is well perceived by the CR technique. This is equally with the case in the oblique view (Figure 3e,f).

Image example 4

CBCT showing a large sialolith in right posterior floor of the mouth. (Figure 4a-f) Figure 4b,d,e show a CR reconstruction. Please note the photorealistic 3D impression of the stone in close proximity to the mandible. This kind of 3D reconstruction can be used preoperatively for surgical planning, for patient information, and for medical teaching purposes. The visual impression of CR gives a high spatial depth and photorealistic surface structures.

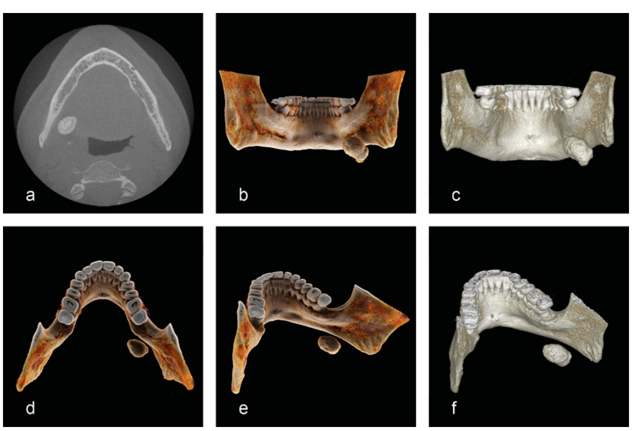

Figure 4 Salivary stone in the right floor of the mouth: (a) axial CBCT view; (b) posterior – anterior CR view; (c) posterior – anterior conventional VRT view; (d) cranio-caudal CR view; (e) oblique CR view; (f) oblique conventional VRT view.

Discussion

In surgical specialties, preoperative three-dimensional understanding of the anatomy depends on factors like the quality of radiological imaging, the quality of radiological software, the surgical experience and the individual`s ability for three dimensional imagination.[11] The ability for 3D imagination differs between individuals and is being tested in various countries as early as in tests for the admission to medical studies. In medical lectures, imaging techniques like CR can help to increase the ability for an improved 3D understanding and imagination.[12]

In various fields of life, high quality computed images are becoming more and more standard. One example is computer gaming, were photo realistic imaging is closing the gap between the imaging quality of computer games and cinema movies. This is also the case for computer animated movies.[13] Thus, we are getting used to computer animated imaging being close to real images. Introducing such techniques to radiology facilitates the approach to read radiological images. Since the introduction of 3D-reconstructions in the early 1980`s,[14] radiologists repeatedly underline that diagnosis is based on 2D-layers in various planes, being “enriched” by a 3D-reconstruction. In medicine, however, 3D-data is getting more important, considering face scans, intraoral scans and the implementation of such mostly stereolithography (STL) data in digital workflows, simulating operative results or serving for the design of patient specific tools like *e.g.* osteosynthesis plates.[15] Seeing this developement towards primary 3D-images, it is of high interest to implement techniques, having been developed for the movie industry, into medical imaging.

Discussing the introduced cases, this implies a spatial understanding of an *e.g.* tooth fracture. The CR image does not only show the external tooth surface (3D) or the fracture line in a 2D plane, but further gives the fracture line within the pulpal cavity.

The underlying physical concept of CR has been described in details previously.[8,9,16] Summarized, CR is based on a similar postprocessing approach of volumetric imaging data as the conventional VRT where basically each image voxel with its assigned transparency and color is artificially lightened to furthermore generate 3D images. The main difference is the more complex and unique lighting model in CR. It applies a global lighting model, which incorporates and propagates thousands of light rays through the image data set. The interaction of those light rays with voxels simulates photon scattering and absorption and results in highly detailed photorealistic images that feature many real world light effects, such as shadows or ambient occlusion.[7,9,16,17]

Based on our initial experience and subjective impression, CR is a helpful tool for a better understanding of complex spatial anatomical structures and enables a facilitated demonstration of pathologies not only to medical doctors but also to non-medical professionals in particular to patients. In the opinion of the authors, another advantage of the high detailed photorealistic appearance of CR reconstructions is the ability to include these for teaching purposes as recently demonstrated by Binder *et al* [12] and frequently embedded in our academic teaching of students and residents. Subsequent systematic studies are of interest to assess the clinical value of CR for dental and maxillofacial imaging compared to 2D CBCT layers and to conventional VRT reconstructions.

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